# LCA methodology applied to the case of the natural reserve WWF, example of self-sufficiency and environmental sustainability

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## ABSTRACT

The project LEGEND has established for the Apulia Region, a useful test to address the issue of monitoring and reduction of environmental impacts, global and local, in a sensitive site as “Le Cesine Farm”, an oasis and protected reserve WWF, demonstrating the validity of the design choices of the application of low enthalpy geothermal energy in environmentally critical sites, and how to monitor the environmental impacts and support environmentally sustainable design choices.

## KEYWORDS

LCA, geothermal plant, low enthalpy geothermal energy, GCHP, buildings efficiency, Apulia Region.

## INTRODUCTION

The geothermal plant created at "Le Cesine" Farm in Vernole municipality (province of Lecce) has been a real challenge for the Puglia region designers that have integrated a technological system with high efficiency in a high natural value context where coexist architectural and environmental constraints.

Figure 1 – Orthophotos of Site Masseria "The Gesine" - Vernole (Le)

An opportunities, realized through the pilot project IPA Adriatic - Legend, where is possible to improve the visitors' center, with attached offices, guest house and cultural space, with high standards of environmental comfort using plant technologies that minimize local and global environmental impacts.

Particularly technological choices and plant engineering have contributed to mitigate the local impacts and the insertion of environmental monitoring systems have been identified where potential environmental interference were managed since the planning stage.

The fundamental on which it has developed the project are:

- ✓ Energy self-sufficiency,
- ✓ Energy sources Integration,
- ✓ Site environmental monitoring.

The energy self-sufficiency is ensured starting from the design phase where system components (heat exchangers, heat pumps and auxiliary services) are sized on the basis of building energy requirements (thermal and electric), which led the design of FV system, composed of 34 of polycrystalline silicon modules, capable of ensuring the entire coverage of the energy requirements of the GCHP system.

The renewable energy integration has been designed to ensure the natural resources available exploitation, depending on the uses of the structure and the building indoor comfort. The geothermal system, the PV and Solar Thermal guarantee, each for its own characteristics, the building energy independence. The combination of these three technologies ensures the best operating conditions in both summer and winter because the temperature range is optimal for the working machines, such as to work in synergy, filling one the deficits of the other, also the photovoltaic source fully covers needs downstream of the systems rationalization.

The environmental monitoring of the site is the aspect of greater complexity to the design phase and for the operating of the peculiarities and environmental constraints. The monitoring plan regard the subsoil and groundwater thermal variation of through a system of thermometer chains placed at different distances from the probes. the indoor comfort monitoring is done through a system of detection levels thermo hygrometric environmental, then is installed a monitoring and evaluating system of the overall energy for the factors of the subsoil and indoor remote controlled and able to intervene on the operating logic of the GCHP system.

Particular attention was paid to the monitoring of the characteristics of the subsurface through the use of Ground Response Test, during design, construction and startup of the plant. We are also conducting experiments for the detection of the thermal characteristics of the subsurface through distributed fiber optic sensors made previously.

As the project "Le Cesine" is funded by the program LEGEND IPA ADRIATIC, in order to assess the overall impacts arising from the use of low enthalpy geothermal technology it was decided to use the LCA methodology to assess the impacts of each plant and compare the results of the new plants and comparing for each plant the impacts produced by the technologies previously in operation.

Although the scope of the "LEGEND Project" did not cover the entirety of the heating/cooling plant for reasons of relevance, , in consideration of the environmental

sensitivity that characterize the area of intervention, and also of the experience already acquired in geothermal and LCA aspects, the Puglia Region wanted to extend the purpose and scope of the study to the operation of the whole system and its form of energy supply, in order to evaluate in their complexity and all the impacts arising from the geothermal system installed.

The start of the LCA study took place in Ferrara in the month of July 2014 during a coordination meeting with the other project partners with whom were shared methodological guidelines for the conduct of the study.

This methodological approach, also because of the poor availability of specific literature, has proved important comparison tool for the success of the study and the validity in terms of reliability and certainty of the results.

These have been developed and reviewed critically by all partners during the duration of the study and currently are a basis for future development of a possible regional standardization.

Figure 1 - coordination table on LCA, Ferrara - July 2014

The study has made the entire life cycle of the geothermal "from cradle to grave", taking as a functional unit 1 MJ of energy produced from geothermal, useful energy to meet the heating requirements of the building in the time period evaluated 20 years.

Six different scenarios were defined for the development of the environmental impacts as well as reflected in Table 1, in order to assess the impacts in different operating conditions, providing the regional legislator an useful support for the assessment of the strengths and weaknesses of the plant from the environmental point of view.

Table 1 – A synthetic picture of the scenarios used for the assessment of impacts

| LCA PHASES | IPA ADRIATIC - LEGEND | | | REGIONE PUGLIA | |
|---|---|---|---|---|---|
| | EU_MIX | IT_MIX | REG_PUG_FV | IT_MIX_ALL | LOCAL_FV_ALL |
| | IPAS1 | IPAS2 | IPAS3 | REG.1 | REG.2 |
| **ENERGY MIX** | | | | | |
| IT MIX | | X | X (OPTIONAL) | X | X |
| RER MIX | X | | | | |
| IT FV MIX | | | | | |
| ENERGY FROM PHOTOVOLTAIC SYSTEM | | | X | | X |
| **LCA PHASES** | | | | | |
| DRILLING + PROBES | X | X | X | X | X |
| MONITORING + PIEZOMETERS | | | | X | X |
| SUPPLY OF HEAT PUMP | X | X | X | X | X |
| DHW + INSTALLATION | | | | X | X |
| PHOTOVOLTAIC SYSTEM + INSTALLATION | | | X | | X |
| INSTALLATION OF GEOTHERMAL SYS. | X | X | X | X | X |
| USE | X | X | X | X | X |
| DISTRIBUTION SYSTEM | | | | X | X |
| **END OF LIFE** | | | | | |
| EOL PROBES | X | X | X | X | X |
| EOL MONITORING | | | | X | X |
| EOL HEAT PUMP | X | X | X | X | X |
| EOL PHOTOVOLTAIC SYS. | | | X | | X |
| EOL ACS | | | | X | X |
| EOL INSTALLATION | X | X | X | X | X |
| EOL DISTRIBUTION SYS. | | | | X | X |
| **COMPARISON TRADITIONAL SCENARIO** | **INNOVATIVE SCENARIO** | | | | |
| | X | X | X | | |

The summary table of the scenarios shows that the study was articulated both to meet the needs of the project guidelines Legend, mainly concerning the geothermal system, and to meet the demands of the Puglia region who wanted to extend the study of environmental impacts to the entire system in accordance with the principle of energy autonomy and complementarity of energy sources.

This methodological choice, as will be seen below, was rewarding for the principles described above in relation to the results obtained.

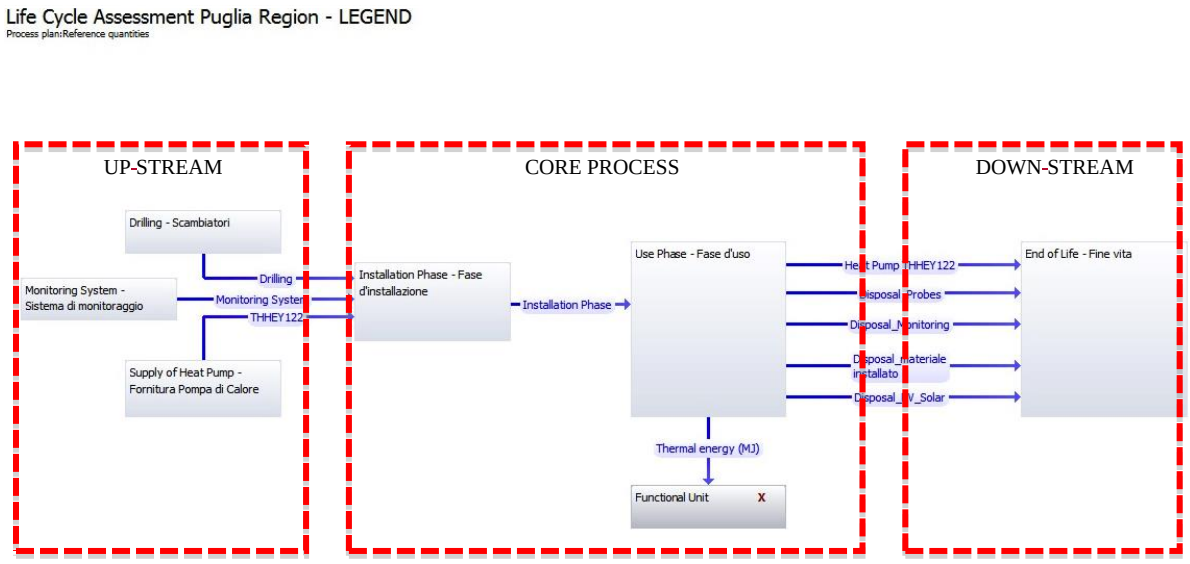


Figure 2 - The flow Articulation for the LCA study

Particular attention has been paid to the collection and critical analysis of data related to the phase of "core processes" (primary data) whose quality and uncertainty evaluation depend directly on the results of the analysis. The activity was carried out using appropriate forms of "data collection" whose compilation involved all the people involved both in the design and in construction of the plant.

As for the secondary data, the data referring to the phases of upstream and downstream, have used the dataset in the database Ecoinvent v.2.2, while for the modeling of flows, it has used the software GABI v.6. This choice was shared by the project partners with whom they shared a critical choices dataset and the subsequent analysis and interpretation of results.

As for the results, all expressed according to the methodology CML 2001- Apr. 2013 and ILCD, and its interpretation, we will proceed to an overview and then proceed to subsequent detailed analysis.

Without prejudice to the main objective to provide the decision maker evaluation elements about the low-enthalpy geothermal systems, analysis and interpretation of the study data was performed with multiple purposes and in particular for:

- understand the plant components of greatest impact ,
- assess the environmental impacts associated with the use phase of the system by comparing the traditional scenario and the innovative scenario (LPG Vs Geothermal plant),
- Provide to the designer the elements for the assessment of technical and technological choices for the next similar projects.

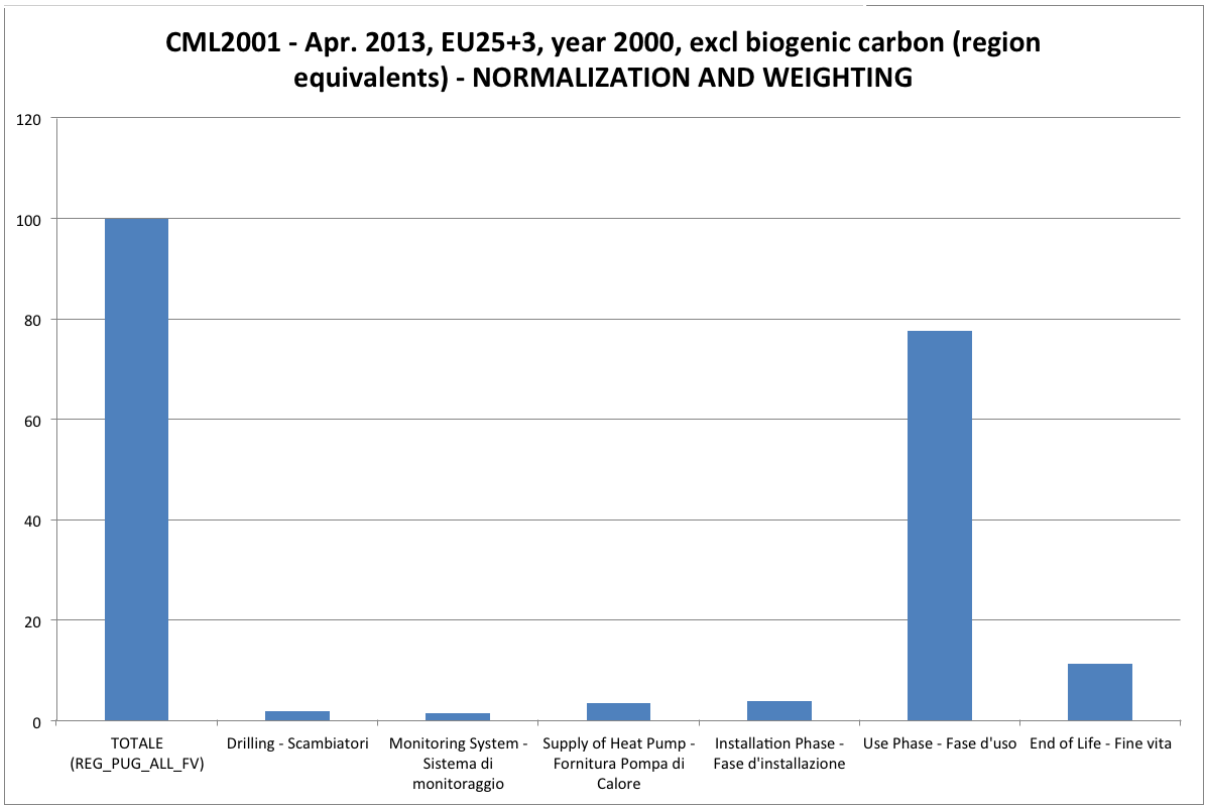


Figure 3 - Assessment of the impact of each process stage with respect to the total plant impact

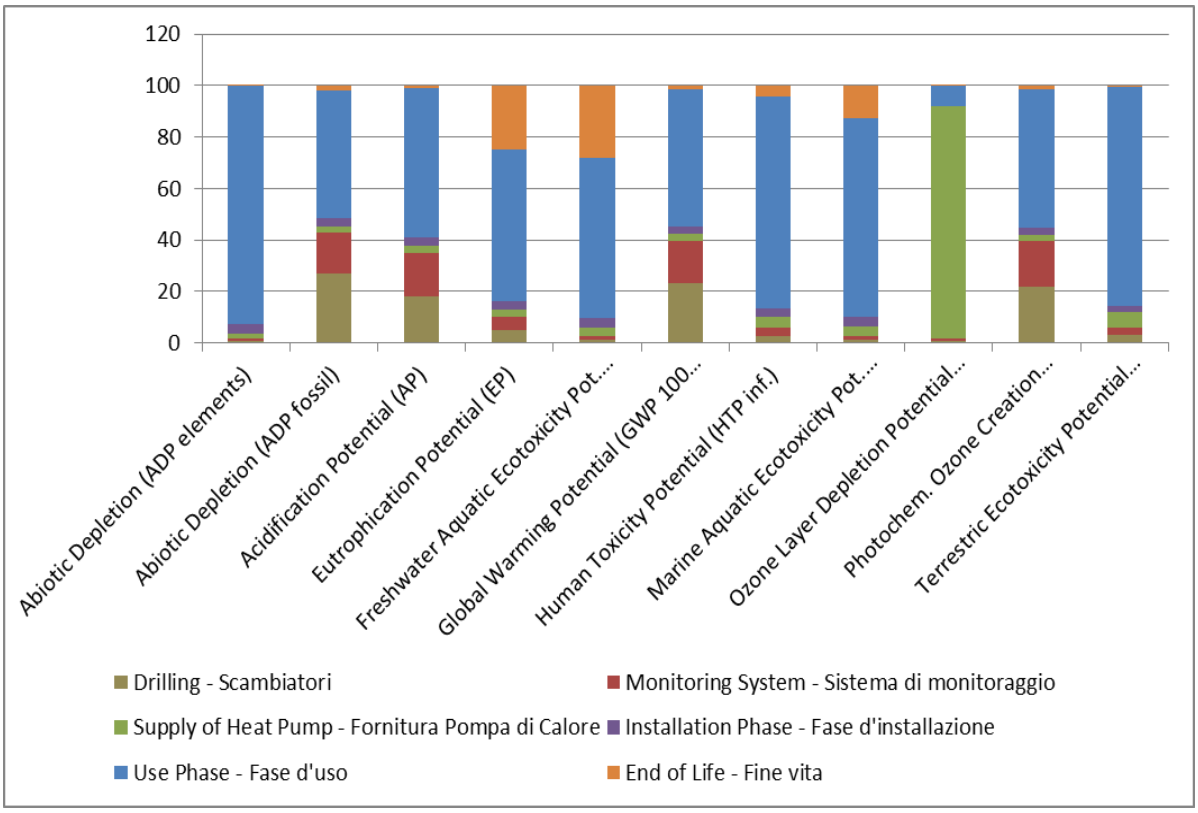


Figure 4 - Effect of each phase with respect to environmental impact categories assessed

The figure 5 shows the strong contribution in most of the categories of impact of the use phase compared to the other phases of the plant life.

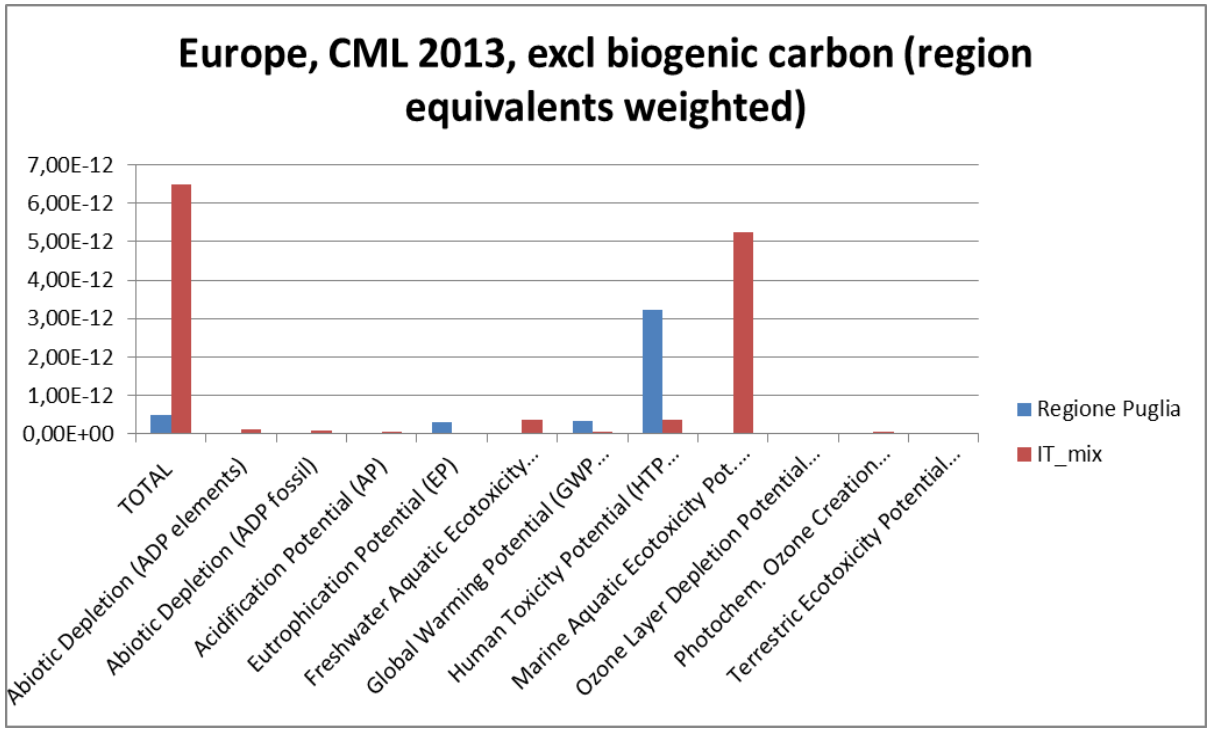


Figure 5 - Comparison of environmental impacts as a result of the change of the energy mix used by the plant

The figure 6 shows how the design choice of autonomy and energy integration in the specific case is rewarding from the point of view of the impacts.

The graphs below are the comparison between the traditional scenario consists of a boiler powered by LPG and innovative scenario (geothermal system). It is important to highlight that the comparison between the scenarios refers to the energy needs of the building over a period of 20 years estimated at 3,414,528 MJ; it should be stated that the innovative scenario was assessed using different energy power mode, considering both the supply of the Italian energy mix, and the supply with green certificates and powered directly by the photovoltaic energy integrated, in order to have a vision as comprehensive as possible.

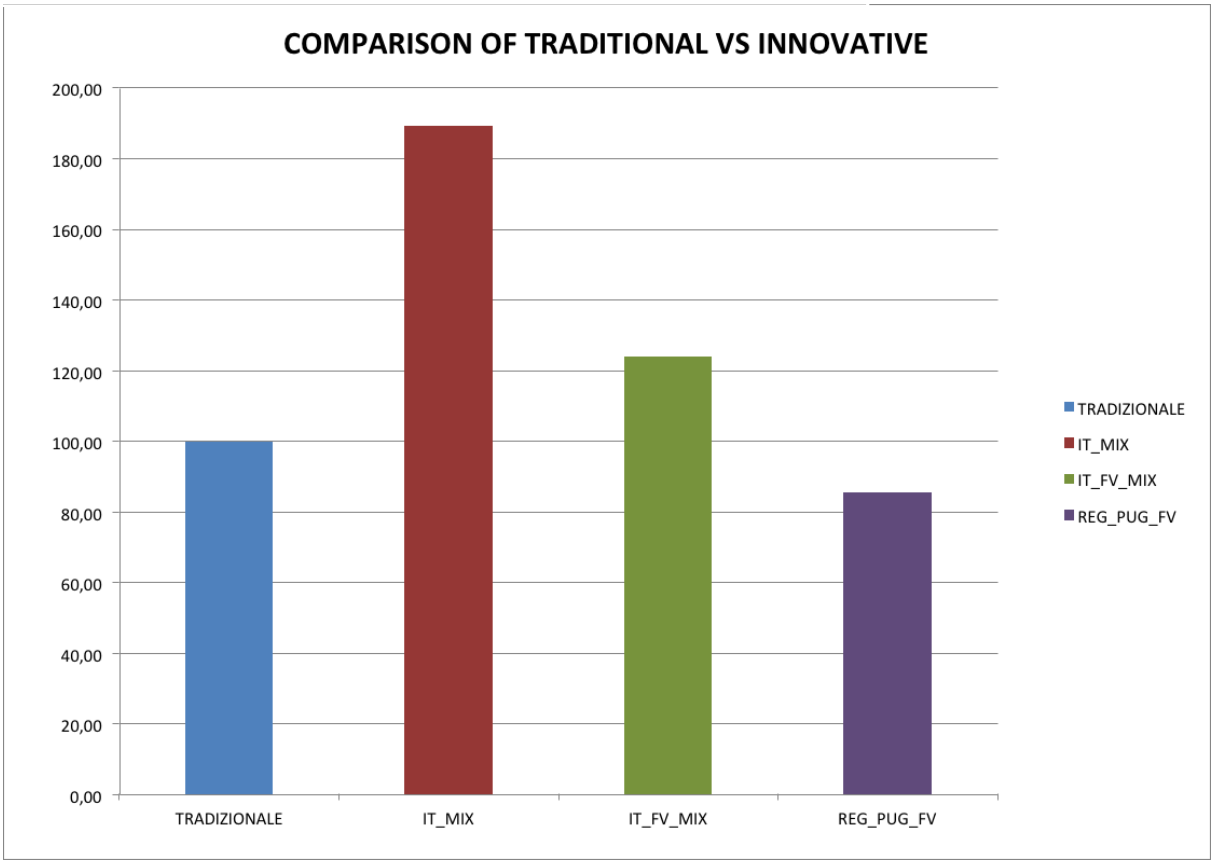


Figure 6 - Comparison of the normalized global environmental impacts of the innovative scenario compared to the traditional scenario

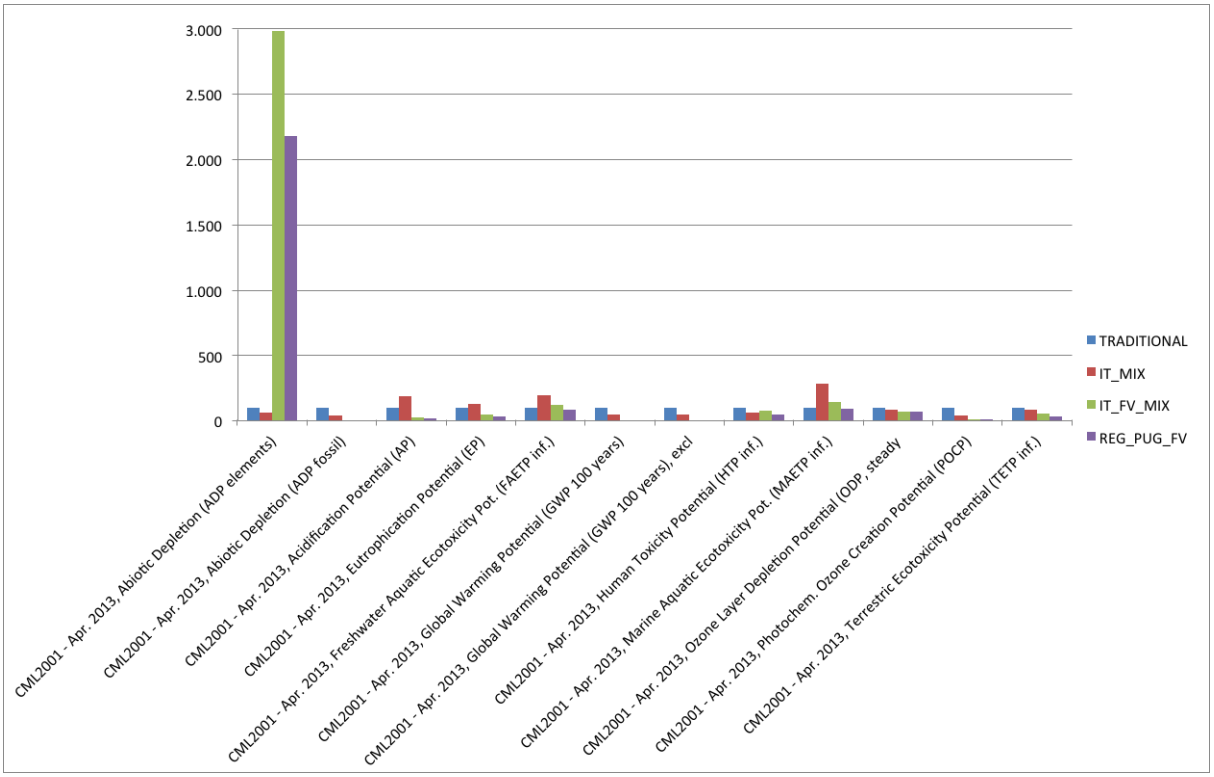


Figure 7 - Comparison between the traditional scenario and the innovative scenarios articulated for the impact categories

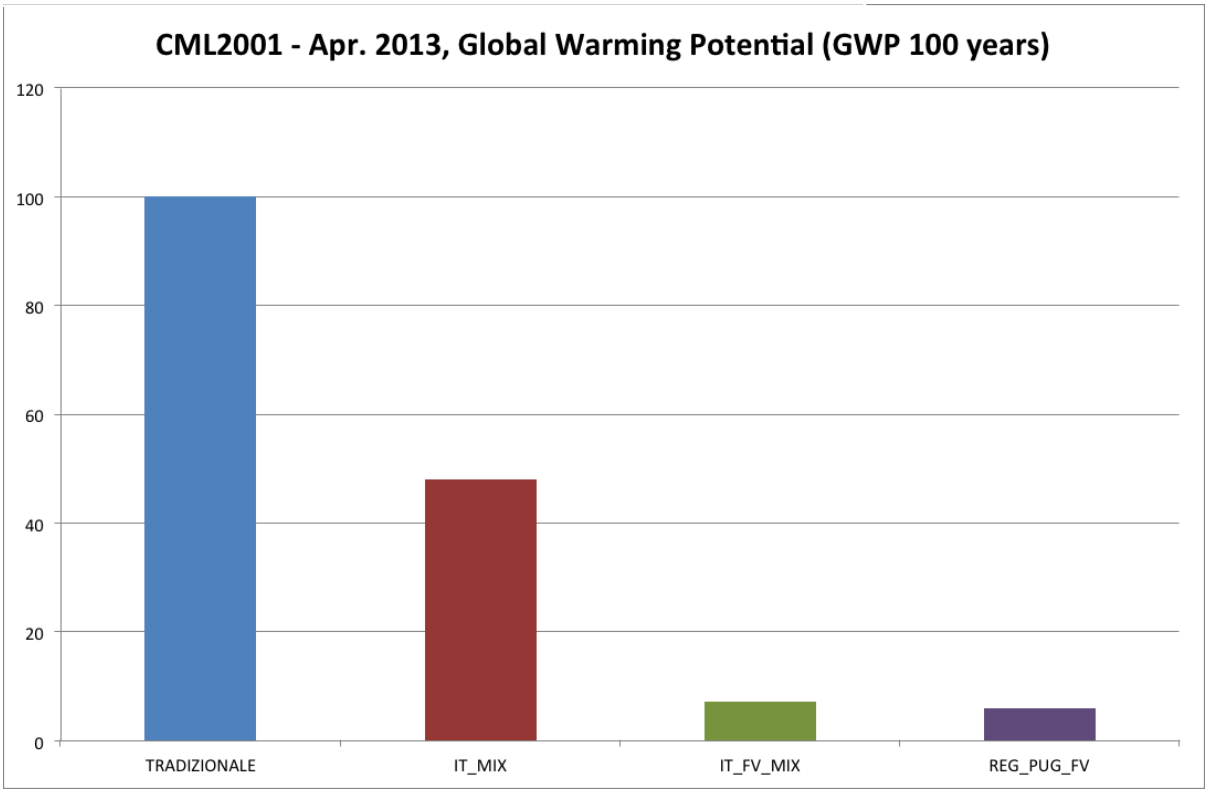


Figure 8 – Normalized comparison between the traditional scenario and the innovative scenarios relative to GWP-100 years.

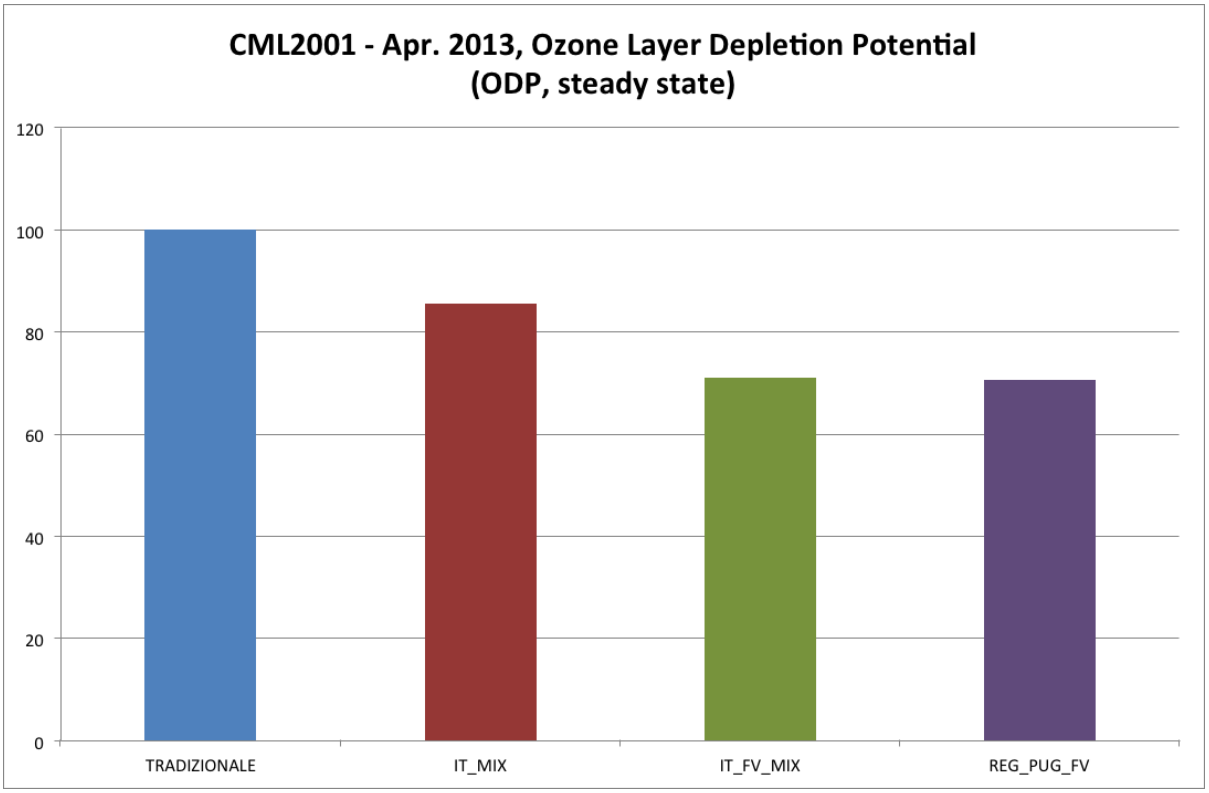


Figure 9 - Normalized comparison between the traditional scenario and the innovative scenarios relative to ODP

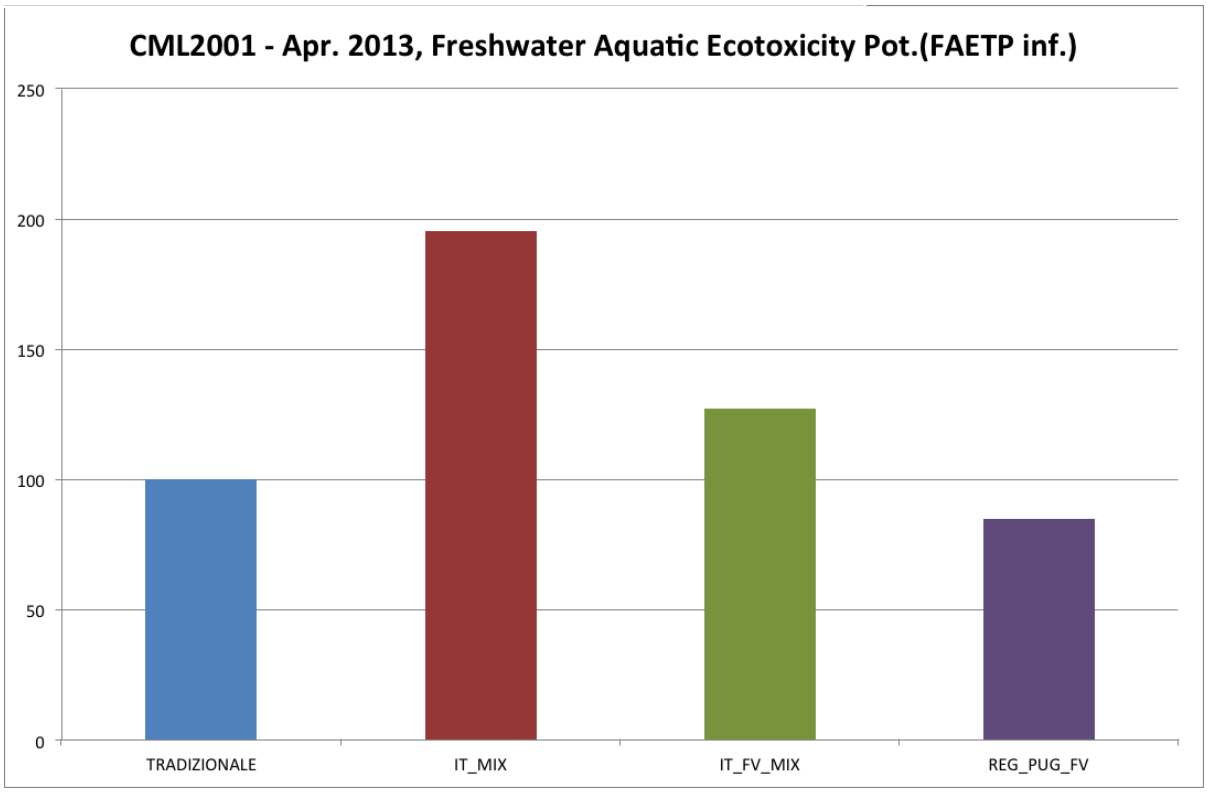


Figure 10 - Normalized comparison between the traditional scenario and the innovative scenarios relative to FAETP

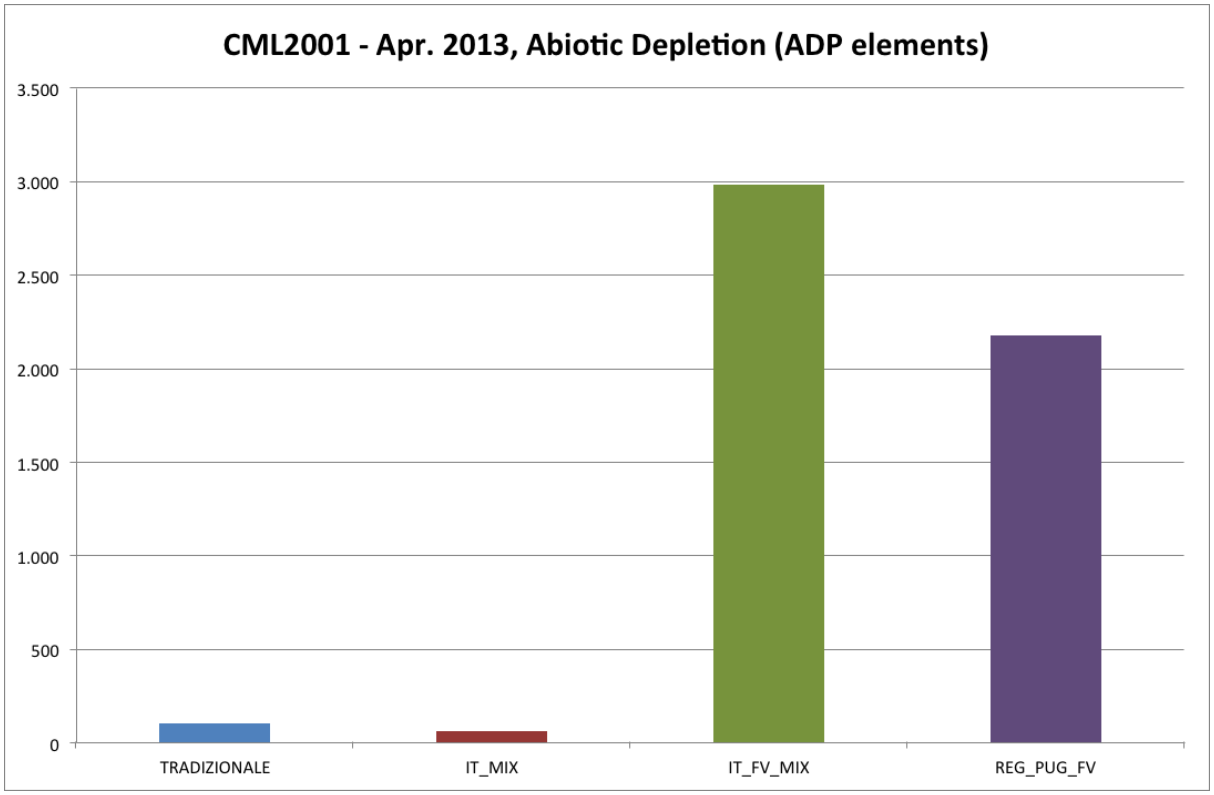


Figure 11 - Normalized comparison between the traditional scenario and the innovative scenarios relative to ADP

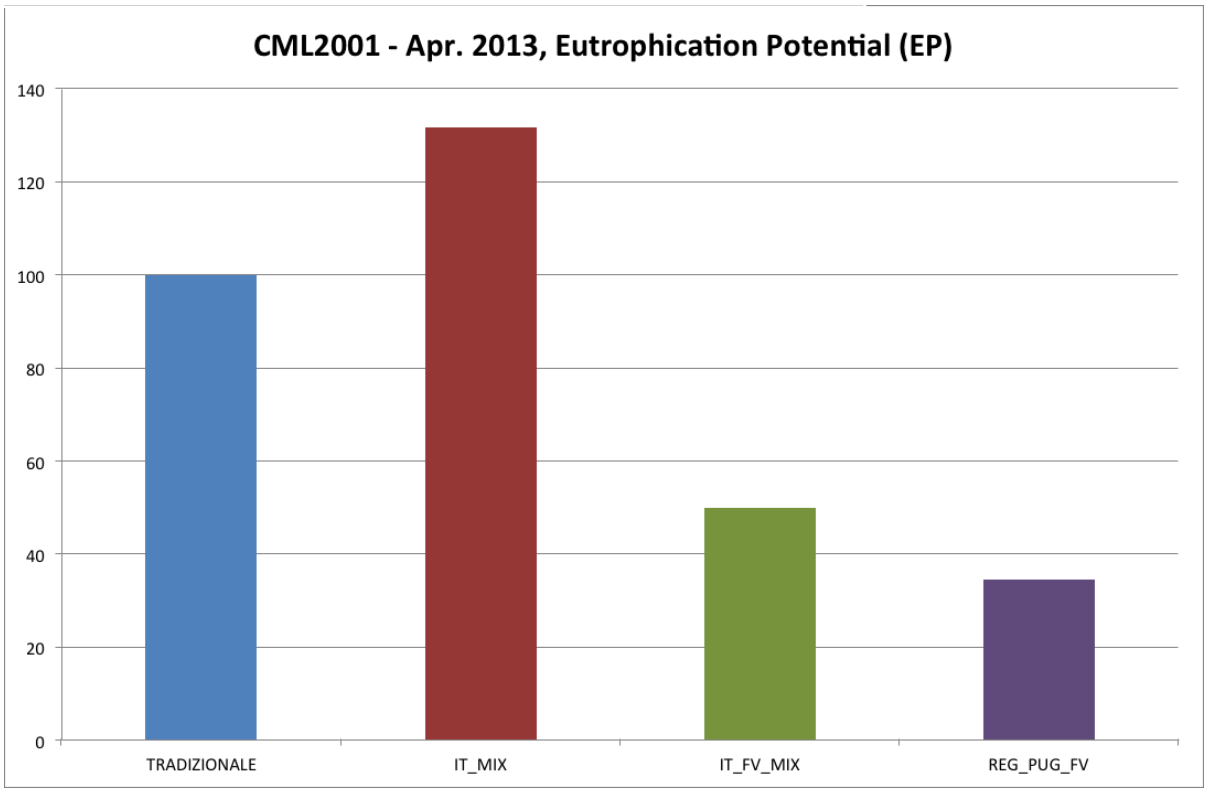


Figure 12 – Normalized comparison between the traditional scenario and the innovative scenarios relative to EP

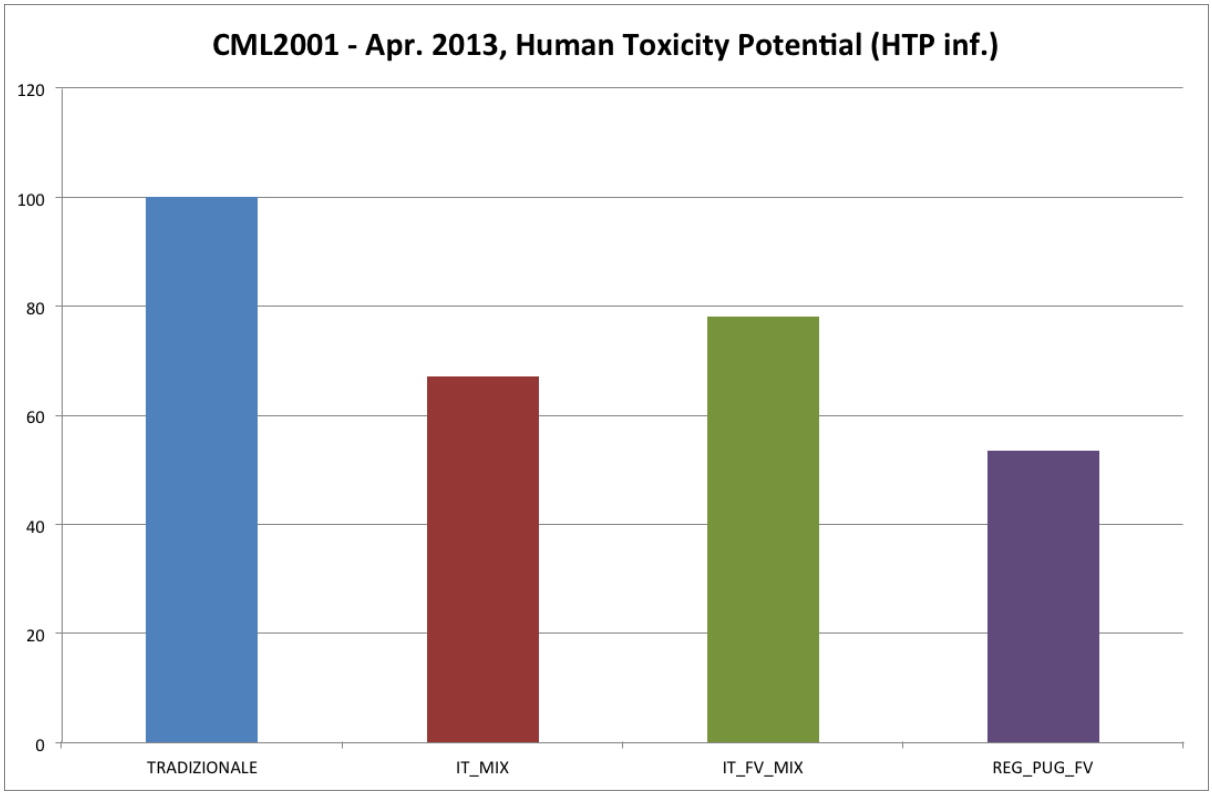


Figure 13 - Normalized comparison between the traditional scenario and the innovative scenarios relative to HTP

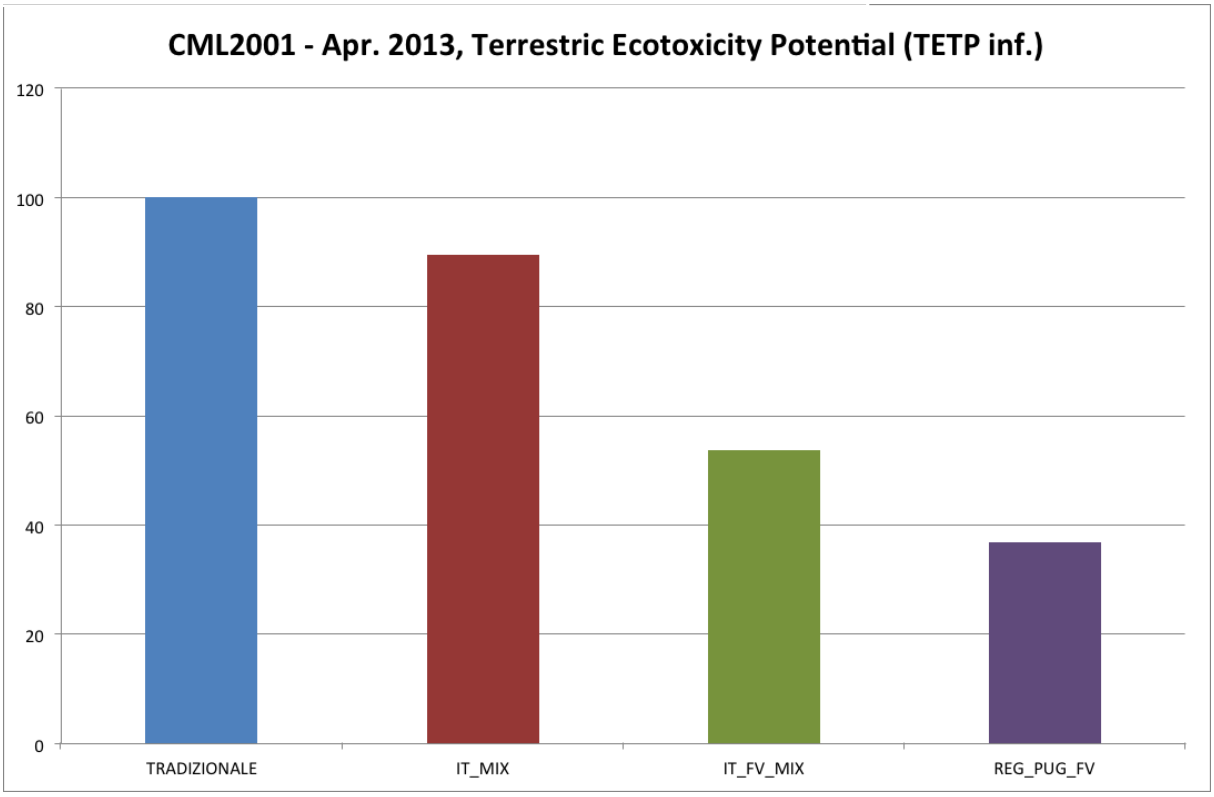


Figure 14 - Normalized comparison between the traditional scenario and the innovative scenarios relative to TETP

As can be seen from the graphs, all the impacts are positive except to Abiotic Depletion indicator (depletion of raw materials). On this, as on other indicators, further analysis have performed to assess the cause and found that this impact is derived by extraction of certain components of the PV system as shown in figure16.

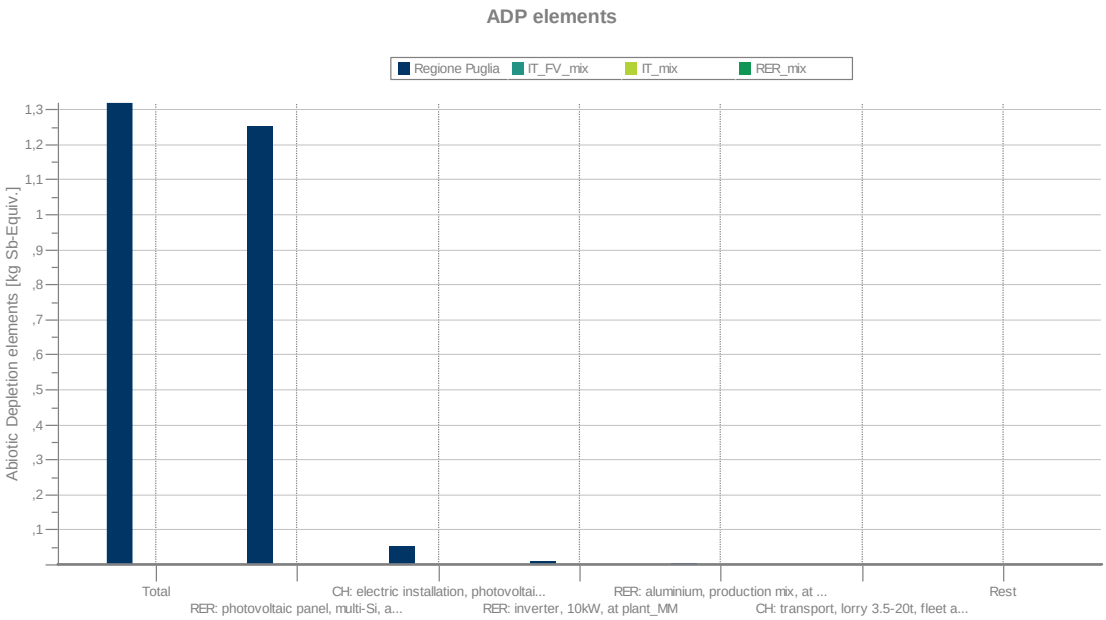


Figure 15 - Analysis of the causes of the impact ADP articulated for plant components

Finally, the following table 2 shows the advantages that the technology of low-enthalpy geothermal enslaved with photovoltaic system attached in order to make the plant self-sufficient, would bring in terms of mitigation and improvement of the principal environmental impacts compared to the geothermal system enslaved by network local distribution of electricity.

Table 2 – the advantages that the technology of low-enthalpy geothermal vs local mix

| | **Puglia Region** | **IT_mix** | **%** |
|---|---|---|---|
| TOTAL IMPACT (NORMALIZATION AND WEIGHTING) | 4,45E-12 | 6,48E-12 | -46% |
| Eutrophication Potential (EP) | 1,43E-14 | 2,52E-14 | -76% |
| Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) | 2,94E-13 | 3,84E-13 | -31% |
| Global Warming Potential (GWP 100 years), excl biogenic carbon | 1,53E-14 | 7,02E-14 | -358% |
| Marine Aquatic Ecotoxicity Pot. (MAETP inf.) | 3,21E-12 | 5,25E-12 | -63% |
| Ozone Layer Depletion Potential (ODP, steady state) | 6,18E-15 | 7,46E-15 | -21% |
| Photochem. Ozone Creation Potential (POCP) | 2,67E-14 | 6,47E-14 | -143% |
| Terrestric Ecotoxicity Potential (TETP inf.) | 1,00E-14 | 1,36E-14 | -36% |

This table shows the advantage that the plant created by Puglia Region at “Le Cesine Farm”, has in terms of environmental impacts in comparison with the system powered by electricity distribution network, without prejudice to the advantages posed by it in comparison with the scenario traditional, results demonstrated and available as an output of the project LEGEND - IPA ADRIATIC.

## CONCLUSION

The pilot plant site in Vernole (LE), “Le Cesine Farm”, adopting the technology of air-conditioned building by geoexchange closed circuit, is a perfect combination of technology, environmental sustainability and economic savings.

The LCA study has allowed us to quantify, with the assumptions made, the environmental footprint that the life cycle of the plant involves a global level, demonstrating the real convenience in terms of environmental sustainability of the design choices adopted.

This technology finds its most effective completion in complete energy self-sufficiency of the structure through the integration of thermal and electrical renewable energy, allowing you to gain competitive advantage not only in terms of environmental sustainability, as shown, but also in terms of energy savings and contribution to the satisfaction of the Community objectives concerning the reduction of greenhouse gas emissions.

The pilot project carried out by the Region of Puglia at "Le Cesine Farm" is therefore the result of the balance between technological innovation and environmental and naturalistic constraints, and certainly can be considered as a reference point for the next interventions in sensitive areas.

The results of the LCA study, although they relate to global impacts, showed a substantially positive impact for all parameters also as a result of the weighting of the results previously reported.

The study done, in terms of guidelines and methodologies for conducting the study, according to the technological and engineering aspects, can be considered an element to support the decision maker to define the next government policies for low enthalpy geothermal plants that will take place in Puglia Region.

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